EVALUATION STATEMENT

On dissertation for awarding the scientific degree "Ph.D. in Physics"
Author of the dissertation: Victor Ivailov Danchev , Ph.D. student at the Faculty of Physics, Sofia State University"St. Kliment Ohridski"
Title of the dissertation: ***Constraints on theories of gravity in the strong regime via analysis of compact astrophysical objects***
Professional Direction: Code 4.1 **"**Physical Sciences"
Author of the evaluation: Professor, Dr.Sc., **Emil Rafaelov Nissimov,** corresponding member of Bulgarian Academy of Sciences (BAS), Institute for Nuclear Research and Nuclear Energy of BAS, retired

I. General description of the presented materials

1. Data on the submitted documents

The Ph.D. candidate Viktor Ivaylov Danchev has submitted the full text of the dissertation together with an extended summary as well as the following documents in accordance with the *Regulations for the Conditions and Procedures for Acquiring Scientific Degrees and Academic Positions at Sofia University "St. Kliment Ohridski'*: Copies of the publications on the subject of the dissertation; Professional autobiography; M.S. degree certificate; Statement of authorship; Attestation for the third year of Ph.D. studies; Reference table for author's contributions; Two declaration forms by cor.-member of BAS Prof. Dr.Sc. Stoycho Yazadjiev certifying the originality of the content and absence of plagiarism in the candidate's dissertation.

The documents submitted by the applicant for the defense are in line with the requirements by the *Law for Professional Development of Scientists in Republic of Bulgaria* and the *Regulations for its Implementation*, as well as the requirements of the *Regulations for the Conditions and Procedures for Acquiring Scientific Degrees and Academic Positions at Sofia University "St. Kliment Ohridski'.*

2. Data about the Ph.D. candidate

Viktor Danchev graduated at the Faculty of Physics of Sofia University "St. Kliment Ohridski" in 2019 within the M.S. program "Theoretical and Mathematical Physics" via M.S. thesis defense with an excellent score under the supervision of Prof. Stoycho Yazadjiev. In the period 2020-2023, he was a full-time Ph.D. student in the doctoral program "Theoretical and Mathematical Physics" again under the scientific supervision of Prof. Stoycho Yazadjiev. Along with his research work on his dissertation, V. Danchev is also an active member of the scientific and engineering-technical team of the modern high-tech Bulgarian company EnduroSat AD active in the field of space

technologies, producing and operating nanosatellites. Since 2021 V. Danchev has held the position of a "technical director" at EnduroSat, responsible for coordinating the company's technical team and its missions. In addition to in-depth knowledge in the field of gravitation, astrophysics and cosmology, related to his Ph,D, thesis work, V. Danchev also possesses highly professional skills in the field of information technologies. He is also an active participant in a large number of authoritative international conferences and science-technical schools in the USA, Austria, Russia, Portugal, Hungary and Bulgaria. In addition to the three publications on the subject of the dissertation (modified / alternative gravitational theories, compact astrophysical objects) in the leading international physics journals with Q1 ranking, V. Danchev is a co-author of a number of other published works in the field of condensed matter physics.

3. General characteristics of author's scientific achievements

The main topic of the dissertation belongs to the new modern fundamental scientific discipline - generalized (extended) gravitational theories and applications in modern astrophysics and cosmology. A brilliant future development is ahead and already realized for this scientific field, the results of which are a contribution to the long-term agenda of the international community of particle and high-energy physicists, astrophysicists and cosmologists to search for answers to such first-rate conceptual scientific questions such as the nature of "dark matter" and "dark energy" - the two main "mysteries" in the evolution of the Universe. In particular, the research in the dissertation is devoted to numerical and analytical modeling of the structure and properties of compact objects in the Universe such as different types of stars and black holes in the context of modern generalizations and modifications of the standard Einstein's general theory of relativity.

As an overall characteristics of candidate's scientific results, one can definitely state that:

a) The scientific publications included in the dissertation work fully comply with, and even exceed, the minimum national requirements (according to Art. 2b, p. 2 and 3 of the *Law for Professional Development of Scientists in Republic of Bulgaria*) and, accordingly, the additional requirements of the *Regulations for the Conditions and Procedures for Acquiring Scientific Degrees and Academic Positions at Sofia University "St. Kliment Ohridski'* for the acquisition of the Ph.D. degree in professional direction 4.1 "Physical sciences". The dissertation is based on 3 publications (all of them with significant contribution by the candidate) in some of the world's most renowned leading physics journals with Q1 ranking: *Physical Review D* and *European Physical Journal C*.

b) The scientific publications included in the dissertation work do not repeat those from previous procedures for acquiring scientific degrees and/or academic positions;

c) There is no proven plagiarism in the submitted dissertation and extended summary.

4. Evaluation of the pedagogical activity of the candidate

The candidate participated in the preparation and teaching of classes in the seminars within the lecture course on ordinary differential equations (winter semester 2021/22) and in the seminars within the lecture course on thermodynamics and statistical physics (summer semester 2021/22) at the Faculty of Physics of Sofia University.

5. Detailed analysis of the candidate's scientific achievements contained in the dissertation

As already noted in p.3 above, the main scientific research problems solved in the dissertation belong to the modern fundamental scientific field of extended/alternative gravitation theories beyond the classical Einstein's general theory of relativity (GR). In this context, the studies of the extremely important class of compact astrophysical objects (black holes, neutron stars and white dwarfs) acquire particular importance, where the attention is primarily focused on the following two particularly actively studied classes of theories: scalar-tensor theories of gravity, including their tensor-multi-scalar generalizations, and scalar Gauss-Bonnet gravitational theories (i.e. gravitational theories with a scalar field coupled to the well-known topological Gauss-Bonnet term).

On one hand, the main interest here is obtaining new effects unattainable with the methods of the classical Einstein GR. On the other hand, special attention is paid to possible inconsistencies of the extended gravitational theory with well-established and observationally confirmed results of GR, which could serve as a criterion for rejection and/or further modifications of the corresponding GR extension.

Briefly, the main results of the dissertation can be formulated as follows:

(1) Slow-rotating topological neutron stars – a new class of compact astrophysical objects in the context of tensor-multi-scalar gravity theories – were studied in detail for the first time in the literature, and the moment of inertia and the corresponding standard universal relations between moment of inertia, mass and radius independently of the equation of state of the compact object were explicitly found.

(2) For the first time in the literature, the orbital and epicyclic frequencies for static and slowly rotating configurations in topological neutron stars, and the innermost stable

circular orbit (important for accretion around the compact object) have been numerically calculated. The results for the two types of scalar field coupling functions are compared. For a monotonic coupling function, there are no significant observational differences with GR, in contrast to the case of a non-monotonic coupling function, which could serve as an observational identification for topological neutron stars.

(3) Important results have been obtained for scalarized neutron stars in the context of scalar-tensor (STT) and scalar-Gauss-Bonnet (sGB) gravitational theories. For the first time in the literature, in the case of STT, a new class of universal relations at a local maximum of the mass for a given branch of solutions is found, where the universality is found to be of the same type as that earlier found in the framework of GR. The possible restrictions on the type of the equations of state of matter are analyzed in conjunction with the interrelationships between the physical properties of the latter. For the scalarization in the sGB class of theories, essential constraints on the parameters of the theory were found via comparison with observations of binary pulsars, from which further constraints were respectively derived for the maximum mass and topological charge of scalarized sGB black holes.

A particularly favorable impression arises by the demonstrated skills of the dissertation's author to implement, adapt and apply modern numerical computer packages based on *C* and *Python* languages for processing and comparing theoretical results with available observational data.

The candidate's scientific contributions can be definitively characterized as:

(a) Development of new theories, hypotheses and methods for worldwide research in the field of modern generalized/extended gravitation theories, astrophysics and cosmology;

(b) Enrichment of existing theoretical knowledge and empirical observations and their further applications in the specified scientific fields.

Currently, the candidate's 3 dissertation papers have 19 independent citations and an h-factor of 3. In all three publications with co-authors, the candidate has made a significant contribution.

6. Critical remarks and recommendations

I have no substantive critical remarks regarding the content of the dissertation and the extended summary. The author adequately orients himself in, and understands in the necessary depth, the essence of the research tasks solved in the dissertation and demonstrates a very good awareness of the relevant scientific literature.

7. Personal impressions about the candidate

The candidate's dissertation and professional CV leave a clear impression of a young scientist with active creative potential and clear prospects for a successful future research career.

8. Conclusion

After having familiarized myself with the submitted dissertation work, extended summery and the other materials, as well as based on the analysis of their significance and the scientific contributions contained in them, I confirm that the author's scientific achievements meet the requirements of the *Law for Professional Development of Scientists in Republic of Bulgaria* and the *Regulations for the Conditions and Procedures for Acquiring Scientific Degrees and Academic Positions at Sofia University "St. Kliment Ohridski"* for the acquisition of a Ph.D. degree. In particular, the candidate satisfies the minimum national requirements in professional direction 4.1 "Physical sciences", and no plagiarism has been established in the dissertation work, the extended summary and the scientific publications submitted for defense. I give my positive assessment of the dissertation work.

II. GENERAL CONCLUSION

Based on the above considerations, **I strongly recommend** to the scientific jury to award the **Ph.D. degree** in professional direction 4.1 "Physical sciences" to the candidate **Viktor Ivaylov Danchev.**

Sofia, April 25, 2023 Evaluator:

(Prof., Dr.Sc. Emil Nissimov, cor.-member of BAS)